

Feeding ecology of the Green-cheeked Parakeet, *Pyrrhura molinae* (Psittaciformes, Psittacidae), in a subtropical forest of Argentina

Analía Benavídez^{1,2}, Ever Tallei³, Echevarría Ada Lilian⁴, Luis Rivera³

1 Centro de Investigaciones y Transferencia de Catamarca, Consejo Nacional de Investigaciones Científicas y Técnicas, Universidad Nacional de Catamarca (CITCA-CONICET/UNCA), Prado 366, K4700AAP. San Fernando del Valle de Catamarca, Catamarca, Argentina

2 Centro de Estudios Territoriales Ambientales y Sociales (CETAS), Facultad de Ciencias Agrarias, Universidad Nacional de Jujuy, Alberdi 47 (4600), San Salvador de Jujuy, Jujuy, Argentina

3 Instituto de Ecorregiones Andinas (INECOA), Consejo Nacional de Investigaciones Científicas y Técnicas, and Universidad Nacional de Jujuy, Av. Bolivia 1711, Y4600GNF, San Salvador de Jujuy, Jujuy, Argentina

4 Instituto de Vertebrados - Fundación Miguel Lillo (FML), Miguel Lillo 251, T4000JFE, San Miguel de Tucumán, Tucumán, Argentina

Corresponding author: Analía Benavídez (analiab87@gmail.com); Ever Tallei (evertallei@gmail.com)

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Abstract

Although there are studies on certain aspects of the feeding ecology of several species of Neotropical parrots, there is scarce ecological information about *Pyrrhura molinae* – a Psittacidae species which is widely distributed in South America and abundant in the Yungas of Argentina. For two years (May 2014 to June 2016), the composition and seasonal variation in the Green-cheeked Parakeet diet in the Yungas Piedmont forest in Jujuy, Argentina were examined. Furthermore, fruiting phenology transects were established to evaluate food resource availability and the patterns of food resource used by the Green-cheeked Parakeet. In 214 food plant trees, it was found that flower and dry fruit availability was highest in the dry season, and fleshy fruit production peaked in the wet season, but these phenology patterns for aged plant species suggest that there were no significant differences in food availability. The consumption of 18 plant species was recorded, being *Celtis iguanaea* (30.73%) and *Trema micrantha* (22.01%) the most consumed species. In terms of food items, fruits were the most consumed items, followed by seeds and flowers and, to a lesser extent, nectar and leaves. Levins' niche

breadth showed varying levels of diet specialisation amongst seasons, which was narrower ($B = 0.28$) in the wet season, indicating specialisation in diet during this season. There was a medium overlap in parakeet diet between seasons (Morisita Index = 0.59). We did not find a statistically significant relationship between resource availability and food use, but expansion and contraction in Levins Index and variation in food items consumed throughout the year and season demonstrate high flexibility in the diet. Like other congeners, the Green-cheeked Parakeet has a flexible diet that could be adjusted to the seasonal availability of food resources. These data may contribute to the design of conservation plans for the species and its habitat.

Keywords

Diet, niche breadth, non-passerines, Piedmont forest, seasonality, Yungas

Introduction

Diet selection has a direct influence on the growth rate, reproductive output and survival of individuals (Ritchie 1990), regulating population dynamics and the intensity of the interactions with other potential competitors (Garb et al. 2000). Dietary knowledge is fundamental to understanding species' niches, habits and roles in communities (Moegenburg and Levey 2003; Munshi-South and Wilkinson 2006).

Food resource availability regulates population levels and reproductive success in several parrot species (Rivera et al. 2020). Psittacids are primary consumers and feed mainly on seeds and fruit pulp, but they also consume flowers, nectar and leaves of a wide variety of plant species (Renton et al. 2015; Benavídez et al. 2018). However, the availability of these resources can vary significantly in space and time (Renton 2001), especially in tropical and subtropical forests, where plant community provides alternative periods of food resource abundance and shortage for animals over the annual cycle (Lee et al. 2014). For these reasons, parrots may adjust their dietary niche concerning fluctuations in food resource abundance (Renton 2001; Matuzak et al. 2008; Renton et al. 2015). Furthermore, parrots may undergo habitat shifts in response to food resource abundance, thus enabling them to track food resource availability (Renton et al. 2015).

Psittacids are one of the most predominant bird groups in the Neotropical Region (Blanco et al. 2018) and they are also one of the most threatened ones (Berkunsky et al. 2018). For these reasons, understanding the relationship of parrot populations to food requirements may help determine key food and habitats for conservation (Renton et al. 2015). In addition, dietary information is important to understand the role of parrots in the functioning of ecosystems (Blanco et al. 2018). Although the number of ecological studies on this group of birds has increased in recent decades, there are still some information gaps for several species (Renton et al. 2015; Benavídez et al. 2018), where feeding ecology and resource requirements are two of the least known aspects of psittacine ecology, particularly the relationship of parrots to food resources (Renton et al. 2015).

The Yungas forest in Argentina exhibits marked seasonality and it is one of the most threatened ecosystems in the country (Brown et al. 2009). In this region, eight

parrot species occur (Blendinger and Álvarez 2009), and *Pyrrhura molinae* (Green-cheeked Parakeet) is one of them. This species is distributed from western Brazil to southern Bolivia and north-western Argentina (Chatellenaz 2009). In the Yungas forest in Argentina, the Green-cheeked Parakeet is the smallest species of parrot, abundant and common, but little is known about feeding ecology and other aspects of its biology in this region. There are some studies of Green-cheeked Parakeet diets in their natural range in Brazil (Ragusa-Netto 2007; Nunes and Santos-Junior 2011). These studies have shown that the Green-cheeked Parakeet is able to exploit a great diversity of food plant items and can adjust its diet to seasonal availability of food resources in dry forest conditions.

In this study, our objectives were to (1) describe the food resource used by the Green-cheeked Parakeet in the Yungas Piedmont forest in Argentina, (2) identify seasonal variations in the diet composition and (3) evaluate the relationship of parakeet diet to food availability.

We present new information about the natural diet of the Green-cheeked Parakeet in the Yungas forest in Argentina with important observations about their seasonal feeding behaviour. This information can be useful for conservation management plans of species and their habitats.

Based on the theoretical background described and our objectives, our study would seem to suggest that the Green-cheeked Parakeet has a broad diet as it responds to seasonal variations in food resource availability.

Methods

Study area

The present study was carried out in the Piedmont forest, the lower altitudinal belt of vegetation in the Southern Andean Yungas forest, in Argentina (Cabrera 1976). Southern Andean Yungas forests hold an important conservation value due to their high biodiversity, which includes several endemic and threatened flora and fauna species (Pidgeon et al. 2015). The Piedmont forest is located between the Yungas mountain forests to the west and the dry forests of the Chaco to the east (Brown et al. 2001). The Piedmont forest is between 400 and 900 m a.s.l and has marked rainfall seasonality with concentrated precipitation in the summer (December-March) (Brown et al. 2001; Mogni et al. 2015), and the year can be divided into wet (October to March) and dry (April to September) seasons. This sector has a high density of woody plant species endemism (30%) and approximately 70% of the tree species lose their leaves during the dry season (Brown et al. 2009). Dominant tree species are *Calycophyllum multiflorum* and *Phyllostylon rhamnoides*, which together with *Anadenanthera colubrina*, *Myracrodruon urundeuva*, *Handroanthus impetiginosus* and *Myroxylon pereirae* constitute the tree canopy of 25 to 35 m height (Brown et al. 2009).

The Piedmont forest has been severely transformed and about 90% of its original surface has been converted into urban, agricultural and pasture areas, amongst

others (Brown et al. 2009). Furthermore, the remaining forests of this ecosystem (approximately 908,000 ha) are mainly exploited by the selective extraction of timber species (Brown et al. 2009). The sites selected for this study are located in the Province of Jujuy, north-western Argentina and are separated by at least 30 kilometres (Finca Yuchán: 23°56'S, 64°54'W; Parque Nacional Calilegua: 23°38'S, 64°35'W and Reserva Privada Ecoportal de Piedra: 24°5'S, 64°23'W, Fig. 1). These sites have not been subjected to anthropogenic disturbance for at least the past 45 years.

Food resource availability

A total of 30 phenology transects of 100 m × 6 m (10 in each site) were established to determine the variation in resource availability (Chapman et al. 1994). Transects were monitored by the same observer during the second week of each month, from May 2014 to June 2016, recording all seeding and fruiting trees with a diameter at breast height (DBH) > 10 cm. For each fruiting tree, DBH and estimated fruit abundance for each site and each month was measured from the sum of DBH and the total number of seeding and/or fruiting trees (Renton 2001). Only parrot food-plant species were included in the analysis at the stage of ripeness when consumed by parrots.

Green-cheeked Parakeet diet

The Green-cheeked Parakeet diet was determined by direct observations of its feeding activity for two consecutive years (May 2014 to June 2016). Feeding observations were performed in the same area and at the same time as the phenology transects. At each of the three sites, a 100 ha grid was established where 60 randomly-located 300 m line transects were delimited. Monthly, the line transects were traversed from sunrise to 12 am, and from 4 pm to sunset, the time of greatest feeding activity of parrot species in general (Renton 2001). When parakeets were detected foraging, date, time, number of individuals, plant species and part of the plant consumed (seed, fruit, leaf, flower and nectar) were registered. We considered the total consumption of the fruit as a whole fruit, i.e. seeds and pulp. Seed consumption was considered when parrots discarded the exocarp and/or endocarp of the fruit to eat only the seed (Jordano 2014). Each event was taken as a single feeding episode. If a parakeet or a group of parakeets changed to another feeding source, either from the same or a different plant species, it was registered as a new feeding event (Altman 1974; Galetti 1993).

Data analysis

The relative frequency of different food items in the diet (seed, fruit, flower and others) was computed as the total number of records of item i (e.g. seed) divided by the total number of records of all items (seed, fruit, flowers and others). A contingency

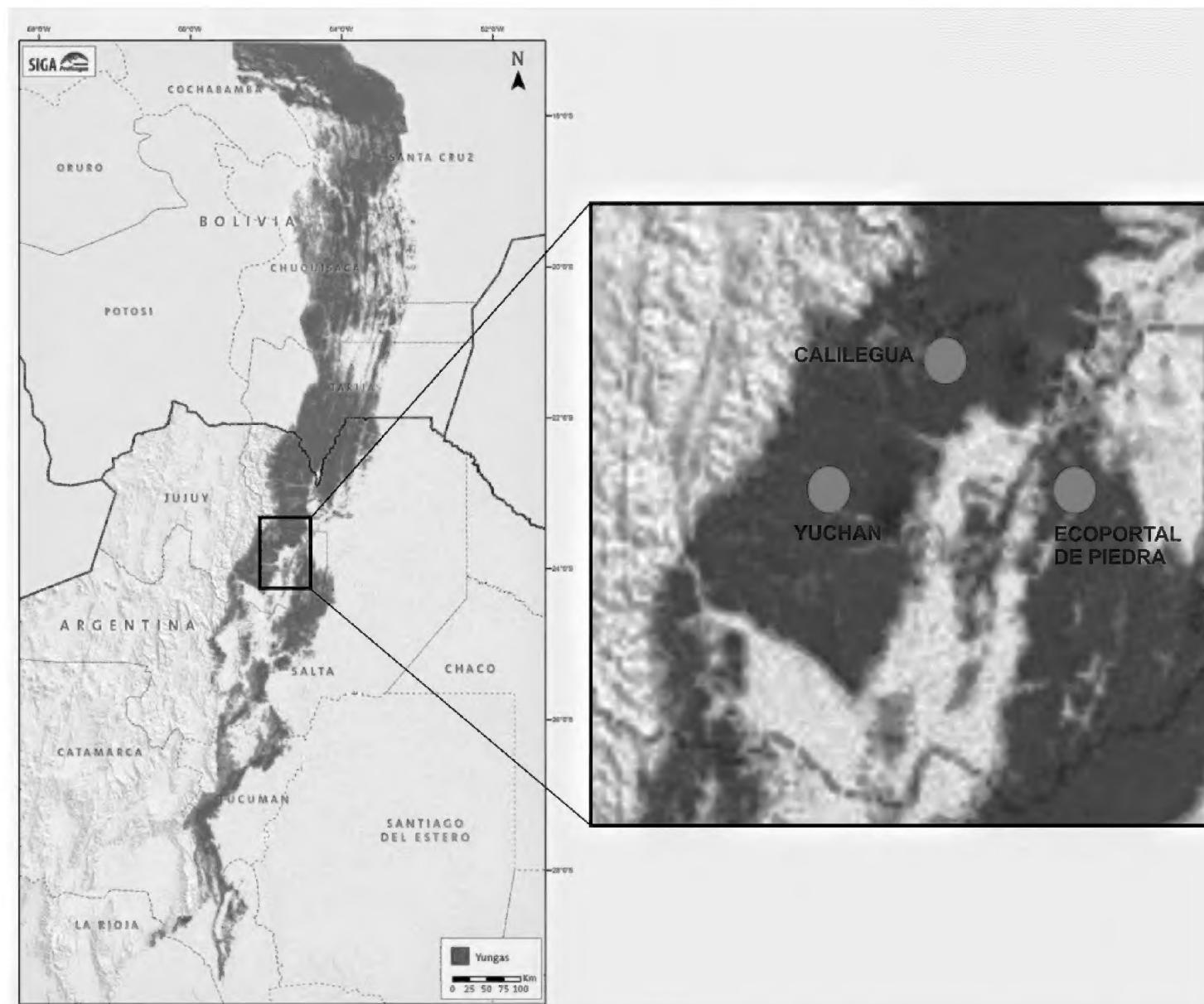


Figure 1. Location of the study area in the Province of Jujuy, Argentina. The black square represents the study area. The red circles represent each study site. The Yungas forests are marked in green. Modified figure from Fundación Proyungas (2007).

Chi-squared test was performed to observe the differences in the number of feeding events and the type of items consumed between two seasons, wet (October to March) and dry (April to September).

To estimate the trophic niche breadth, we used Levin's measure of standardised niche breadth (Colwell and Futuyma 1971), calculated as $BA = (Y^2/\Sigma N^2) - 1/n - 1$, where Y is the total number of parrots feeding, N is the number of parrots associated with each plant species and n is the total number of food plant species. A value close to 0 indicates dietary specialisation, i.e. the species disproportionately selects some plant species, and a value close to 1 indicates a broad diet with a proportional use of several plant species (Krebs 1998). The overlap in parakeet diet between dry and wet seasons was evaluated using Morisita Index (Morisita 1959) that ranges between 0 (no overlap) and 1 (total overlap). Both indices were calculated for each season of the year taking into account the monthly data of both years.

Data from the phenology transects were used to determine food resource abundance and availability for the Green-cheeked Parakeet. We defined food re-

sources available to the Green-cheeked Parakeet based on our field observations of foraging parakeet. Seasonal variation in food resource abundance was analysed by the U Mann-Whitney test on the sum of DBH and the total number of fruiting trees. Previous Kolmogorov-Smirnov analysis demonstrated a normal distribution for the variables of numbers of fruiting trees ($D = 0.23; p < 0.12$) and the sum of DBH of fruiting trees ($D = 0.24; p < 0.10$). To evaluate the relationship between food resource availability and the parakeet diet, the Spearman rank correlation was used and the significance of these correlations using the 'cor.test' function in R software (R Development Core Team 2020) was tested. Statistical analyses following Zar (1999) were carried out in R software version 4.0.1 (R Development Core Team 2020).

Results

Food resource availability

A total of 214 food plant trees of ten species from seven families were recorded in the phenology transects. *Anadenanthera colubrina* was the most abundant fruiting tree species (55% of fruiting trees). Piedmont forest showed no statistically significant differences for seasonal availability on food resource for both estimators ($U = 156, N_1 = N_2 = 12, p < 0.68$ for number of fruiting trees; $U = 167, N_1 = N_2 = 12, p < 0.32$ for sum of DBH). In the dry season, the food resource abundance was greater, where most species of trees have dry wind-dispersed fruit. At the end of the dry season, there was a decrease in the food resources availability, but there was a slight peak of flower production. In the wet season, there were peaks in fleshy fruit abundance.

Diet composition, seasonality and correlation with food availability

Over the two years, the Green-cheeked Parakeet consumed 18 plant species from ten families (Table 1; Fig. 2), and only two of them were exotic (*Morus nigra* and *Citrus sinensis*). With a total of 220 feeding bouts, fruits represented 66.67% of the items consumed, followed by seeds (16.51%) and flowers (10.09%) and, to a lesser extent, leaves (4.59%) and nectar (1.83%). Some plant species were represented by more than one item (Table 1). The plant family with the highest number of species in the diet was Fabaceae (four species). *Celtis iguanaea* (30.73%; 67 feeding bouts) and *Trema micrantha* (22.01%; 48 feeding bouts) had the greatest number of feeding bouts. During the first year, 124 feeding bouts and the consumption of 15 plant species were registered, while, in the second year, the consumption of 11 species was detected. *Citrus sinensis*, *Cedrela angustifolia*, *Jacaranda mimosifolia*, *Solanum riparium*, *Tessaria integrifolia* and two unknown species were consumed only in the first year, while *Maclura tinctoria*, *Tipuana tipu* and *Vachellia aroma* were consumed only in the second year.

Table 1. Plant species and food items used as food resources by *Pyrrhura molinae* in the Yungas Piedmont forest in Jujuy, Argentina, from May 2014 to June 2016. FYL: Finca Yuchán Ledesma, RPEP: Reserva Privada Ecoportal de Piedra, PNC: Parque Nacional Calilegua. Starred words indicate exotic species.

Plant Species	Items	Month	Feeding bout	Site	Number of individuals
Anacardiaceae					
<i>Astronium urundeuva</i>	fruit	Sep, Oct, Nov, Dec	17	FYL, PNC	98
Asteraceae					
<i>Tessaria integrifolia</i>	fruit	Mar, Apr	9	PNC	26
Bignoneaceae					
<i>Handroanthus impetiginosus</i>	nectar	Sep, Oct	4	FYL, PNC	24
<i>Jacaranda mimosifolia</i>	nectar	Oct	1	PNC	7
Cannabaceae					
<i>Celtis iguanaea</i>	fruit	Jan, Feb, Apr, May, Nov, Dec	67	FYL, RPEP	436
<i>Trema micrantha</i>	fruit	Jan, Feb, Mar, Apr	48	FYL, PNC	320
Fabaceae					
<i>Vachellia aroma</i>	seed	Jun	8	RPEP	28
	flower	Oct	2	RPEP	5
<i>Anadenanthera colubrina</i>	seed	Aug, Sep	5	FYL	53
	leaves	Jul, Aug, Sep	10	FYL	65
<i>Parapiptadenia excelsa</i>	seed	May, Jul, Aug	10	FYL, RPEP, PNC	47
<i>Tipuana tipu</i>	seed	Jan	1	FYL	23
Juglandaceae					
<i>Juglans australis</i>	flower	Jan, Feb, Mar	14	FYL, RPEP	77
Meliaceae					
<i>Cedrela angustifolia</i>	seed	Aug	1	FYL	28
Moraceae					
<i>Morus nigra*</i>	fruit	Sep, Oct	3	RPEP	25
<i>Maclura tinctoria</i>	fruit	Oct	2	FYL	15
Rutaceae					
<i>Citrus sinensis**</i>	seed	Aug	11	FYL	52
	flower	Sep	3	FYL	54
Solanaceae					
<i>Solanum riparium</i>	fruit	Mar	1	FYL	10
Unidentified species					
sp1	fruit	Mar	1	FYL	5
sp2	nectar	Oct	2	FYL, PNC	19

The parakeet diet varied between seasons and there were statistically significant differences in the frequency of feeding bouts ($X^2_1 = 10.47; p < 0.001$) and the frequency of item types consumed ($X^2_4 = 79.83; p < 0.001$). The principal items consumed during the dry season were fruits of *C.iguanaea* ($n = 18$ feeding bouts) and seeds of *C.sinensis* ($n = 11$) and *Parapiptadenia excelsa* ($n = 10$). Only in this dry season, the consumption of leaves of *Anadenanthera colubrina* was observed. In the wet season, the most consumed items were fruits of *C.iguanaea* ($n = 49$) and *T. micrantha* ($n = 40$), along with flowers of *Juglans australis* ($n = 14$).

The niche breadth was variable amongst seasons and it was wider in the dry season ($B = 0.69$) than in the wet season ($B = 0.28$), with a high overlap in food items between seasons (Morisita Index = 0.59). The narrow diet niche breadth in the wet season indicates a tendency to concentrate food on only a few of the available resources. There were significant correlations between numbers of parakeet feeding and numbers of feeding bouts ($r_s = 0.94, t_{(22)} = 13.05, p < 0.001$, Table 2, Fig. 3).



Figure 2. The Green-cheeked Parakeet (*Pyrrhura molinae*) feeding on *Citrus sinensis* seed in the Yungas Piedmont in Argentina. Photo: Rodrigo Aráoz

Table 2. Matrix of Spearman's rank correlation coefficients between food resource availability and diet of *Pyrrhura molinae* from Yungas Piedmont in Argentina. Bold values indicate $P < 0.05$.

	Number of plant individual	Feeding bout	Number of parakeets	Levins Index
Number of plant individual	1			
Feeding bout	-0.24	1		
Number of parakeets	-0.29	0.94	1	
Levins index	-0.30	0.21	0.19	1

Discussion

Food resource availability

Food resource availability for the Green-cheeked Parakeet did not demonstrate significant differences in this study, possibly due to the lack of food resource species in tree phenology samplings. In the study area, Benavídez (2018) found that the Piedmont forest has a marked seasonality with two different seasons, the dry (May-October) and the wet (November-April) seasons, where the plant community shows phenological behaviour, distinguishing flowering peaks in the dry season and two fruiting peaks, one in wet (fleshy fruit) and another in the middle of the dry season. Annual flowering and fruiting likely result from an influence of environmental factors. Several studies on dry forests have demonstrated that rainfall seasonality is the main factor that explains fruiting patterns in dry forests (Bullock and Solis-Magallanes 1990; Ragusa-Netto

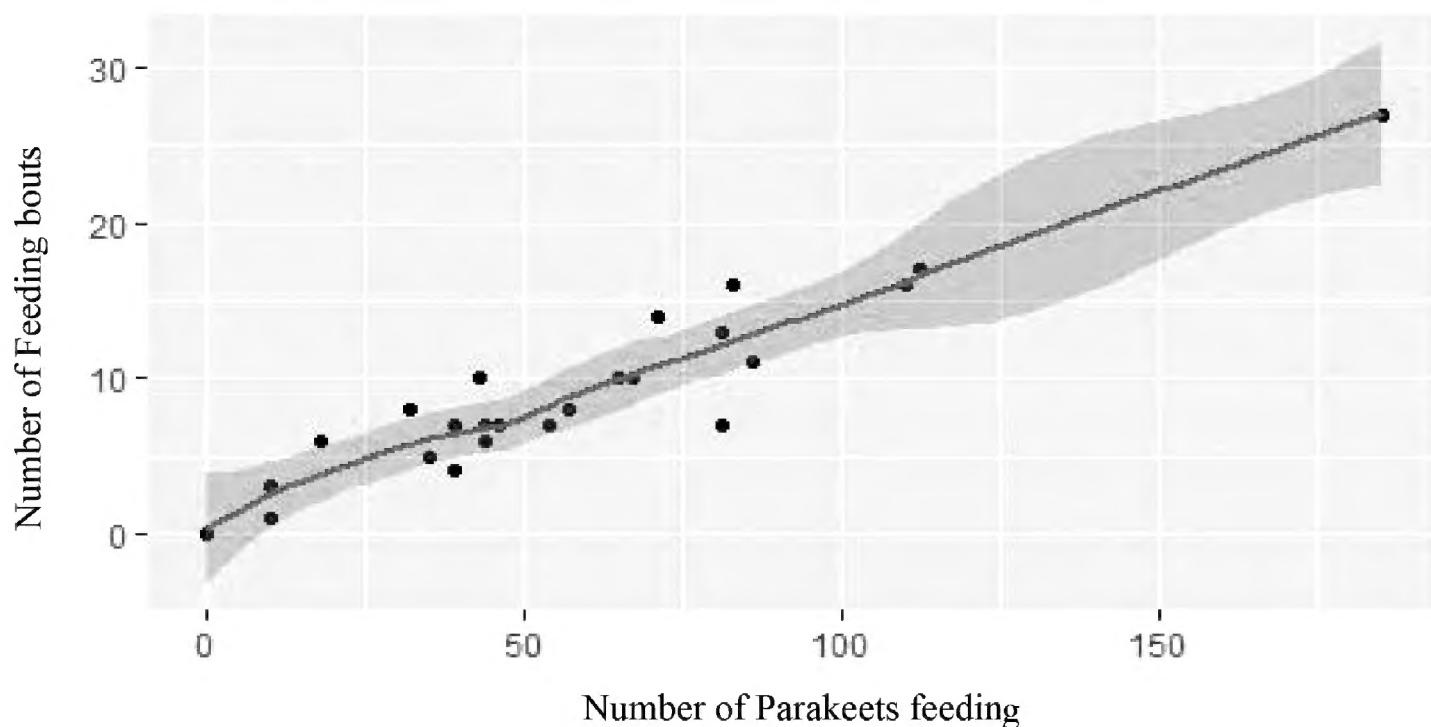


Figure 3. Linear relationship between the number of parakeets feeding and the number of feeding bouts as illustrated by the output of a Spearman's rank correlation, in which the 95% confidence interval is represented by the grey shading.

and Fecchio 2006; Valdez-Hernández et al. 2010). The phenology patterns of a vegetal community affect the availability of food items for the parrot assemblages, which may employ a combination of strategies of diet switching, habitat shifts and movements to track food resources (Renton et al. 2015).

Diet composition, seasonality and correlation with food availability

The Green-cheeked Parakeet shows a broad diet in the study area, consuming a wide variety of plant species and items (from fruits to leaves) and varying throughout the year and seasons. These results are similar to the studies carried out in a forest in south-western Brazil, where the Green-cheeked Parakeet consuming between 16 to 20 plant species (Ragusa-Netto 2007; Nunes and Santos-Junior 2011) and similar other Pyrrhuras species (Roth 1984; Toyne et al. 1992; Kristoch and Marcondes-Machado 2001; Botero-Delgadillo et al. 2010, 2013; Buitrón-Jurado and Sanz 2016) were observed. One common feature of feeding habits in *Pyrrhura* genus is the extensive consumption of few, but abundant available food resources (Ragusa-Netto 2007; Botero-Delgadillo et al. 2010). Parrots are considered adaptable, consuming a great variety of plant species, as well as adapting to novel foods in modified environments, causing conflicts with farmers (Matuzak et al. 2008; Barbosa et al. 2021). However, the population decline of some parrot species has been linked to the decline of keystone plant resources (Berg et al. 2007; Renton et al. 2015). Our results showed a large consumption of *Trema micrantha* and *Celtis iguanaea* by the Green-cheeked Parakeet. Both native plant species could be a key food resource to the Parakeets in the Yungas forest and the potential reduced availability of these species,

as a result of habitat fragmentation, may have consequences in the maintenance of wild parakeet populations.

In this study, fleshy fruit is the most consumed item and this fact was not unexpected given its high presence in the diet of *Pyrrhura* and other species of small and medium-size psittacids (Renton et al. 2015; Botero-Delgadillo et al. 2013; Benavídez et al. 2018). The high percentage of fruit in the diet of small parrots has been attributed to body size (Matuzak et al. 2008; Renton et al. 2015; Benavídez et al. 2018) and it is linked to energy requirements, due to the fact that small birds need more carbohydrates, because they display higher mass-specific metabolic rates (Suarez and Gass 2002). Furthermore, the high consumption of fruits, especially fruits with small seeds (e.g. *Trema micrantha*), might indicate the potential ecological role that this species might be playing in seed dispersal and, therefore, in the plant community structure (Blanco et al. 2018). Blanco et al. (2015) found that the Green-cheeked Parakeet in the dry tropical forest of the Bolivian inter-Andean valleys could act as a mutualist by dispersing seeds of native plants. Piedmont forest is currently one of the most threatened Andean forests in South America (Brown 2009) and, as a consequence, current functions and services provided by the Green-cheeked Parakeet and other parrot species in this forest requires further research, to have a better understanding of the Yungas ecosystem.

The Green-cheeked Parakeet might respond to changes in food availability, showing flexibility in the items consumed throughout the year and being mostly granivorous during the dry season, and more frugivorous/florivores during the wet season. Seasonal diet switching has been noted in other neotropical parrots (Galetti 1993; Renton 2001; Ragusa-Netto 2007; Botero-Delgadillo et al. 2010). We found that the Green-cheeked Parakeet exhibits a narrower dietary niche breadth in the wet season, which corresponds to a decrease in food resource availability. Fruit consumption occurs mainly during the wet season, when the availability of this resource increases in the Piedmont forest (Pacheco and Grau 1997; Brown et al. 2009), while seed and nectar are consumed mainly during the dry season. Consumption of flowers and nectar is important for some neotropical parakeet species (Galetti 1993; Cotton 2001; Ragusa-Netto 2005, 2007; Lee et al. 2014), especially in seasonal forests which provide an alternative food resource during the driest period of the year, when fruits and seeds are scarce (Ragusa-Netto 2005). The ability to exploit available resources may enable parrots to increase energy intake and fitness benefits in seasonal environments (Renton et al. 2015). Although we did not find any correlation between the parakeet diet and food availability, the expansion and contraction in the Levins Index and variation of food items consumed throughout the year and season demonstrate high flexibility in the diet and it might be closely related to the temporal variation in the availability of food resources. Furthermore, the absence of such correlation could also be associated with the absence of other food resources (e.g. understorey species) in the phenology transect. This is the case with *Trema micrantha* and *Celtis iguanaea*, two species that are relatively abundant

in the understorey of the Piedmont forest and are the main plant species consumed by parakeets. The inclusion of understorey species in future studies of food resource availability needs to be taken into consideration.

Conclusions

The present study demonstrates a high flexibility in Green-cheeked Parakeet diet which could be closely related to temporal variations in different food resources. The information provided in this study and in other recent studies on the genus *Pyrrhura* is an advance on the knowledge of the ecology and behaviour of this genus. The high consumption of *Trema micrantha* and *Celtis iguanaea* fruits reinforces the idea that the Green-cheeked Parakeet could act as mutualist by dispersing the seeds of these species in the Yungas forest. Furthermore, both plant species could be key resources for Parakeets. Considering that the Piedmont forest is currently one of the most threatened Andean forests in South America, further research is absolutely necessary to elucidate the related process with habitat use, ecological requirements and other aspects to ecology of parrots in the Yungas forest. This information is essential for understanding the functional role of parrots in ecosystems and for helping to develop conservation strategies for parrot species and their habitats.

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